1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA), under the Superfund Innovative Technology Evaluation (SITE) Program, evaluated the ability of the Glass Furnace Technology (GFT), developed by Minergy Corporation (Minergy) of Waukesha, Wisconsin to treat sediment containing polychlorinated biphenyls (PCBs) and metals. This introductory section provides background information about the SITE Program, discusses the purpose of this Innovative Technology Evaluation Report (ITER), and describes the proposed technology. This ITER describes additional information about the SITE Program, the GFT, the SITE demonstration, and Minergy's claims about the technology. The SITE evaluation of the GFT involved testing of two phases, a drying phase and a melting phase. The majority of activities undertaken for this evaluation involved the melting phase of Minergy's technology. Key individuals for this project are listed at the end of this section.

1.1 THE SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION PROGRAM

The primary purpose of the SITE Program is to advance development and implementation and to establish the commercial availability of innovative treatment technologies applicable to Superfund and other hazardous waste sites. The SITE Program was established by the EPA Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) in response to the 1986 Superfund Amendments and Reauthorization Act (SARA), which recognized the need for an alternative or innovative treatment technology research and demonstration program. The SITE Program is administered by the ORD National Risk Management Research Laboratory in the Land Remediation and Pollution Control Division, headquartered in Cincinnati, Ohio. The overall goal of the SITE Program is to implement procedures of research, evaluation, testing, development, and demonstration of alternative or innovative treatment technologies that can be used in response actions to achieve protection of human health and welfare and the environment. Under the SITE Program, an innovative technology's performance in treating an individual waste at a particular site is evaluated.

The SITE Program consists of four component programs: (1) the Demonstration Program, (2) the Emerging Technology Program, (3) the Monitoring and Measurement Technologies Program, and (4) the Technology Transfer Program. An innovative treatment technology can be evaluated under one of these programs. This ITER for the GFT was prepared under SITE's Demonstration Program. The objective of the Demonstration Program is to provide reliable performance and cost data on innovative technologies so that potential users can assess a given technology's suitability for specific site cleanups. To produce useful and reliable data, demonstrations are conducted at hazardous waste sites or under conditions that closely simulate actual waste-site conditions.

Technologies are selected for the SITE Demonstration Program through EPA's annual requests for proposals. ORD staff review the proposals to determine which technologies show the most promise for use at Superfund sites. Technologies chosen must (1) be at the pilot- or full-scale stage, (2) be innovative, and (3) have some advantage over existing technologies. Mobile or transportable technologies are of particular interest. Implementation of the SITE Program is an ongoing effort involving EPA's ORD, OSWER, various EPA regions, and private business concerns, including technology developers and parties responsible for site remediation.

EPA and the innovative technology developer establish responsibilities for conducting demonstrations and evaluating the technology. The developer is typically responsible for demonstrating the technology at the selected site and is expected to pay any costs for the transport, operation, and removal of related equipment. EPA is typically responsible for evaluating the performance of the technology during the demonstration. This responsibility includes project planning, site preparation, technical assistance support, sampling and analysis, quality assurance (QA) and quality control (QC), report preparation, information dissemination, and transport and disposal of treated waste materials.

At the conclusion of the demonstration, EPA typically prepares a Demonstration Bulletin (2-page summary), a Technology Capsule (10- to 12-page summary), an ITER, and a Technology Evaluation Report (TER). These reports provide an evaluation of all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. Testing procedures, performance and cost data, and QA/QC standards also are presented. A Demonstration Bulletin for Minergy's GFT was published in August 2002. The ITER is discussed in detail in the following sections, and the TER provides relevant information on the technology, emphasizes key results of the demonstration, and includes detailed analytical results.

1.2 INNOVATIVE TECHNOLOGY EVALUATION REPORT

The ITER is intended for use by EPA remedial project managers, EPA on-scene coordinators, contractors, and other decision-makers, who are implementing specific remedial actions. The ITER provides details about the technology, SITE evaluation procedures and findings, and unit cost information to aid in evaluating the technology. In particular, the report includes information on cost and site-specific characteristics, and it discusses advantages, disadvantages, and limitations of the technology.
Each SITE demonstration evaluates the performance of a technology in treating a contaminated material or media. Successful field demonstration of a technology at one site does not necessarily ensure that it will be applicable at other sites. Data from field demonstrations may require extrapolation for estimating the operating ranges in which the technology will perform satisfactorily. Only limited conclusions can be drawn from a single field demonstration. This ITER provides information of the GFT developed by Minergy and includes a comprehensive description of the demonstration and its results.

1.3 PROJECT DESCRIPTION

The GFT process is designed to treat PCB- and mercury-contaminated sediment. The GFT project is funded by a cooperative agreement among between Minergy, Wisconsin Department of Natural Resources (WDNR), and EPA's Great Lakes National Program Office (GLNPO). Because the GFT is not designed to be used on any one particular site, detailed information regarding site location, geology, and hydrology is not necessary for the understanding of this demonstration project.

The GFT was developed by Minergy of Waukesha, Wisconsin. Minergy originally developed vitrification technologies to process wastewater sludge into glass aggregate that, Minergy contends, could be sold as a commercial product. Minergy modified a standard glass furnace to treat river sediment containing PCBs and metals, and the SITE Program evaluated the resultant technology's ability to treat sediment containing PCBs and mercury.

With WDNR oversight and funding from a coalition of six paper companies with ties to the Lower Fox River, called Fox River Group, the sediment used in this evaluation was obtained from the Lower Fox River during the 1999 Sediment Management Unit (SMU) 56/57 pilot dredging project. This project included hydraulic dredging, onshore dewatering, filter pressing, and treatment with lime. The PCB-containing sediment dredged during the project was transported to, and disposed of in, a landfill in Green Bay; Wisconsin. However, approximately 70 tons of sediment was segregated in four roll-off boxes and stored at the Brown County Landfill for use in the Minergy GFT demonstration. The stockpiled, filter-pressed sediment was characterized as containing approximately 50 percent solids.

The Lower Fox River sediment has been subjected to various studies over the last 15 years. Sediment in the vicinity of SMU 56/57 consists of 60 to 80 percent silt, with lesser amounts (0 to 40 percent each) of sand and clay. PCB concentrations as high as 710 parts per million (ppm) have been detected in samples collected from SMU 56/57. However, analytical results for sediment stockpiles prior to, and immediately following, sediment acquisition for the GFT evaluation indicated PCB concentrations of less than 50 ppm and mercury concentrations of about 1 ppm.

Minergy required that the sediment contain no more than 10 percent moisture for the melter to operate at optimal efficiency. Minergy researched available sediment drying technologies and determined that a indirect heat disc or paddle dryer unit was the most appropriate drying technology for the GFT treatment process. Because no large-scale dryers of this type were available for use, a suitable, bench-scale Holoflite® dryer, located at the Hazen facility in Golden, Colorado, was used to dry a representative amount of sediment under similar conditions to those in a large-scale dryer unit. The dryer unit was configured to allow sample collection of all waste and process streams, including off-gases.

The SITE evaluation of the GFT focused on the melting phase where contaminant reduction would occur. The melting phase of the process was evaluated at a pilot-scale melter that was specifically designed for the SITE evaluation at Minergy's facility in Winneconne, Wisconsin. The sediment, glass aggregate, and waste streams were analyzed for contaminants of concern (COCs) before and after (1) treatment in the bench-test sediment dryer, and (2) processing through the melter. COCs included PCBs; dioxins and furans; metals, including mercury; and SVOCs. Metals were characterized by analysis for the eight Resource Conservation and Recovery Act (RCRA) Toxicity Characteristic metals, which include mercury.

1.4 THE GLASS FURNACE TECHNOLOGY

The following sections provide a general description of the GFT, as well as Minergy's melter and its specific configuration.

1.4.1 General Description of the Glass Furnace Technology

The information in the following 3 paragraphs has been paraphrased from Minergy's Final Report on Sediment Melter Demonstration Project for WDNR, submitted in December 2001 (Minergy 2001).

Glass furnaces have been used for decades in industrial glass manufacturing. The process design of a glass furnace is focused on melting low-energy feedstock; that is, materials with low energy content, as measured in kilojoules (kj). Feedstock, consisting primarily of silica sand, melts in the furnace, and the molten product is cooled to form glass. Silica is one of the primary constituents of river sediment and, in this case, the GFT vitrifies the river sediment, with the expectation of destroying COCs and creating a useable aggregate as a final product. Minergy claims that other thermal destruction processes are too costly to be appropriate for use on river sediment, because the sediment has limited fuel value. Many other processes rely on the significant organic content (fuel content) of the feed material, but because limited energy is contained in sediment, large quantities of auxiliary fuel or electric power are needed. Minergy and WDNR have successfully completed two phases of a multiphase feasibility study (FS) to evaluate GFT as a remediation alternative. The first phase (Phase I) involved characterizing the mineral composition of river sediment to estimate glass quality, durability, and melting points. Data gathered during Phase I indicated that characteristics of river sediment are consistent throughout the river and are favorable for producing a quality glass product. Based on mineral composition, combustibility, moisture content, and costs to operate, Minergy claims that analysis of the sediment indicates vitrification technology is more appropriate than incineration for treatment of river sediment.

In Phase II, sediment from the Lower Fox River was test-melted in a crucible to determine glass characteristics and qualities of the vitrified sediment, both alone and when augmented with other materials (flux mixtures) to control melting temperatures and improve the physical properties of the glass aggregate product. Four different test "recipes" were included in the crucible melts, and the sediment was successfully melted into glass in all four tests. Data obtained during Phase II were used to develop (1) a proposed "recipe" for melting river sediment into glass aggregate, and (2) preliminary engineering designs for the pilot-scale facility proposed for Phase III. The preliminary engineering analysis indicated that it was not practical or cost-efficient to use an existing glass furnace for GFT testing. This analysis indicated that it would cost as much to retrofit an existing facility to specifications needed to melt the sediment as it would to build a pilot glass furnace to the same specifications. Project stakeholders also discovered that most existing glass manufacturing facilities are too large to accommodate a limited duration test.

Results of the FS indicated that capital and operating costs of the GFT provide for an economically viable option for treating contaminated river sediment.

1.4.2 Minergy Corporation's Glass Furnace Technology

Minergy's intent with the GFT process was to treat dewatered sediment from the dredging site. The GFT process for the demonstration is shown in the diagram in Figure 1-1.

Sediment would be delivered in dewatered form, in the range of 45 to 55 percent solids (by weight). The first step of the process involves drying the sediment to about 10 percent moisture. Drying the sediment increases the overall efficiency of the process by limiting the amount of moisture in the melter, thereby reducing the physical volume of the feed and maintaining high processing temperatures. Several technologies were available for thermal drying. Ideally, gases from the drying step would be directed into the glass furnace or into another destruction device to control COC emissions.

In the planned GFT process, sediment passes from the drying system into the glass furnace. The glass furnace is a refractory-lined, rectangular melter. The refractory is a special type of brick that is resistant to chemical and physical abrasion, has a high melting point, and provides a high degree of insulating value to the process. The furnace, configured with oxygen and natural gas delivery systems with control and safety devices, attains internal temperatures of about 1,600 °C (2,900 °F). At this temperature, sediment melts and flows out of the furnace as molten glass.

The molten material is then quickly cooled in a water-quench system to form the glass aggregate product. Minergy claims that the glass aggregate can be stored and handled similarly to conventional quarried aggregates. Some off-site crushing and screening would be required to meet particle size specifications of certain aggregate markets.

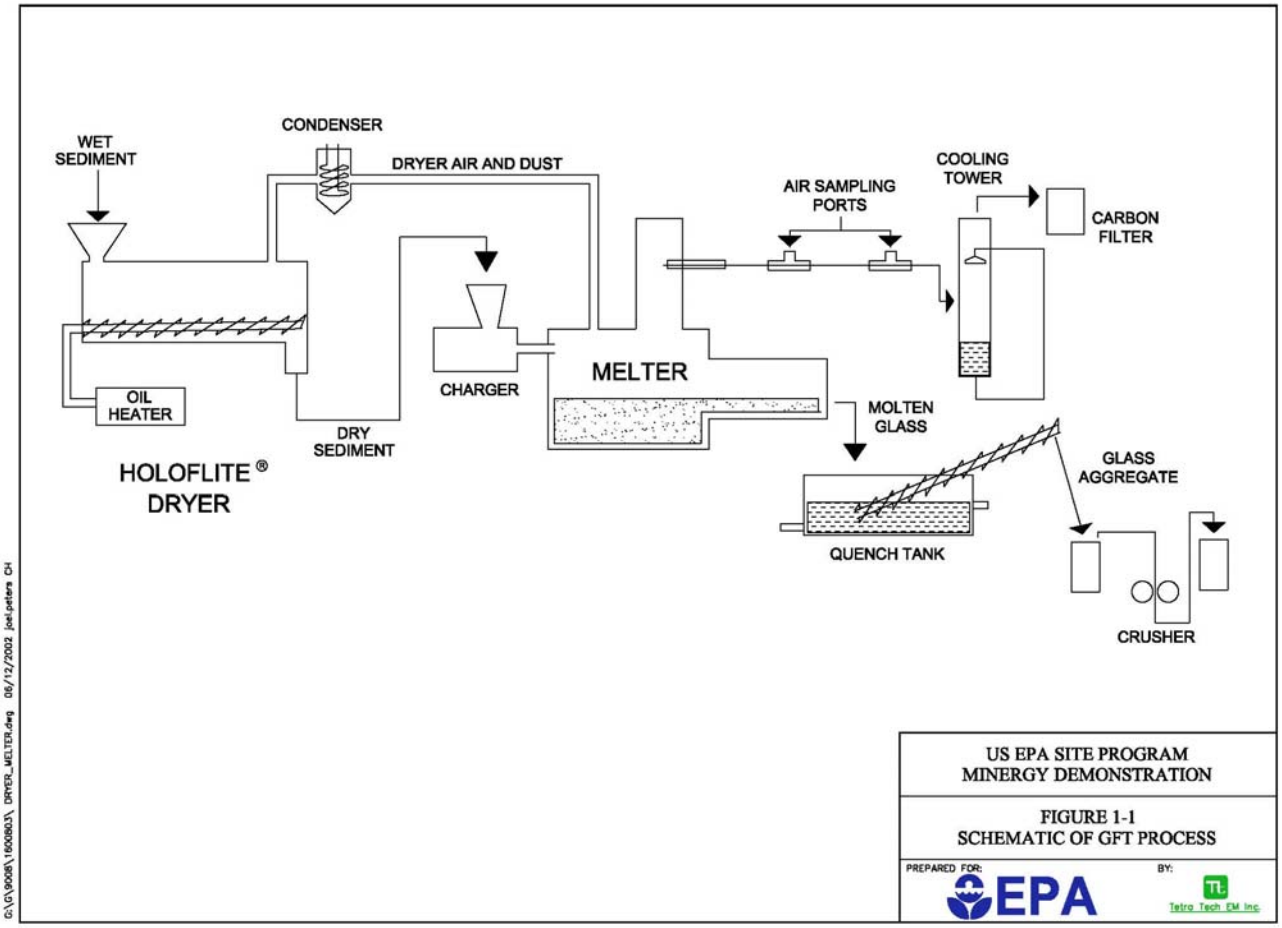

Figure 1-1 SCHEMATIC OF GFT PROCESS

Minergy expects that the high-temperature environment in the melter will completely destroy any organic compounds that may be present. In addition, trace metals in the sediment are expected to be stabilized in the glass aggregate product and are anticipated to be biologically and chemically inert. Minergy claims that off-gas treatment is simplified and energy efficiency is improved by the melter's use of purified oxygen, rather than atmospheric air, as the oxygen source. Minergy has made modifications to a standard glass furnace design, which have been incorporated to best suit this application, including the following:

- The height of the furnace was increased from typical designs to provide additional volume for destruction of organic vapors. The additional height increases the residence time that organic contaminants spend within the furnace.

- Use of a water quench system to quickly harden the molten glass and increase the inert characteristics of the final product. Glass melters typically use annealing or other slow-cooling processes to enhance glass clarity and other product qualities. These product qualities are not applicable to the manufacture of glass aggregate because of its intended final use as a construction product.

- Use of a "shallow" glass pool inside the melter. Glass melters typically have deeper pools of glass inside the melter, taking advantage of the low opacity of the glass being produced. Molten sediment is quite opaque, thereby reducing energy transfer by radiation.

- Use of refractory brick selected to resist corrosive and abrasive qualities of molten sediment.

- Use of flux materials selected to enhance properties of molten sediment material.

Minergy hopes to construct GFT treatment facilities in locations where sediment removal is chosen as a remedial approach, and to treat contaminated sediment as an alternative method to landfilling.

1.4.3 Site-specific Dryer Configuration

A dryer, determined by Minergy to be of suitable configuration, was located at the Hazen facility in Golden, Colorado. The Holoflite® dryer was a small, bench-scale unit with the capacity to process 14 pounds per hour (lb/hr) (6.4 kilograms per hour [kg/hr]) of dredged-and-dewatered (45 to 55 percent moisture) sediment. To produce an adequate feed material for introduction into the dryer, portions of the sediment were dried and mixed with dredged-and-dewatered sediment to reduce the stickiness of the material. Mixing dredged-and-dewatered sediment with dried sediment is a standard materials-handling practice that creates better flow characteristics.

The dryer itself consisted of a small metal box about 76 centimeters (30 inches) long that contained two hollow, oil-filled augers that turned slowly. The oil in the augers was heated to about 180 °C (360 °F), and the heat of the augers drove moisture from the sediment. The turning of the augers moved the sediment through the dryer to the end, where it fell into a flask. Water in the form of steam escaped from the dryer through a manifold in the top and was condensed and collected. The dryer reduced the moisture content of the sediment to less than 10 percent. Figure 1-2 shows the dryer used for the technology demonstration.

1.4.4 Site-specific Furnace Configuration

The pilot-scale glass furnace, or melter, was designed to simulate a full-scale production unit for generation of glass aggregate from sediment. To produce an adequate simulation, some assumptions were made regarding the full-scale melter, based on typical glass-manufacturing practices. Melter characteristics are presented in Table 1-1.

Figure 1-2 shows the melter as constructed for the demonstration. The pilot-scale melter area was 0.9 square meters (10 square feet), with a 2:1 aspect ratio, meaning that it was twice as long as it was wide. The melter was fired with oxygen and natural gas to use the best available control technology for nitrogen-related emissions and particulate matter. The melter had eight split-stream, oxygen-fuel (oxy-fuel) burners to approximate the eight burners used in a full-scale melter. The charger was a standard screw feeder used universally in glass furnaces. The screw feeder was chosen for its ability to tightly seal the hopper to the charger and the charger to the furnace. Tight seals minimized dust formation during introduction of the dried sediment into the melter. The charger was similar in size to those used in a full-scale unit, but was retrofit with a small screw barrel and flights for the pilot-scale melter.

The height of the glass processing area was slightly increased to provide additional volume for destruction of organic vapors. The flue was located in the front of the melter, which is not the traditional location for oxy-fuel furnaces. However, this configuration allowed any fine particulate matter that became entrained

TABLE 1-1
PILOT-SCALE MELTER CHARACTERISTICS
(supplied by Minergy)

Parameter	Measurement
Aspect Ratio (Length/Width)	2:1
Area	0.9 square meters (10 square feet)
Melting Rate	0.49 square meters per ton (5.4 square feet per ton)
Dwell Time	6 hours
Gas Usage	1.8 MM kj per hour (1.7 MM Btu per hour)
Oxygen Usage	1.1 cubic meters per hour (35 cubic feet per hour)
MM Btu/ton	22 MM kj per ton (21 MM Btu per ton)
Output	2.0 tons per day

Notes: Btu = British thermal unit
kj = Kilojoule
MM = Million Million

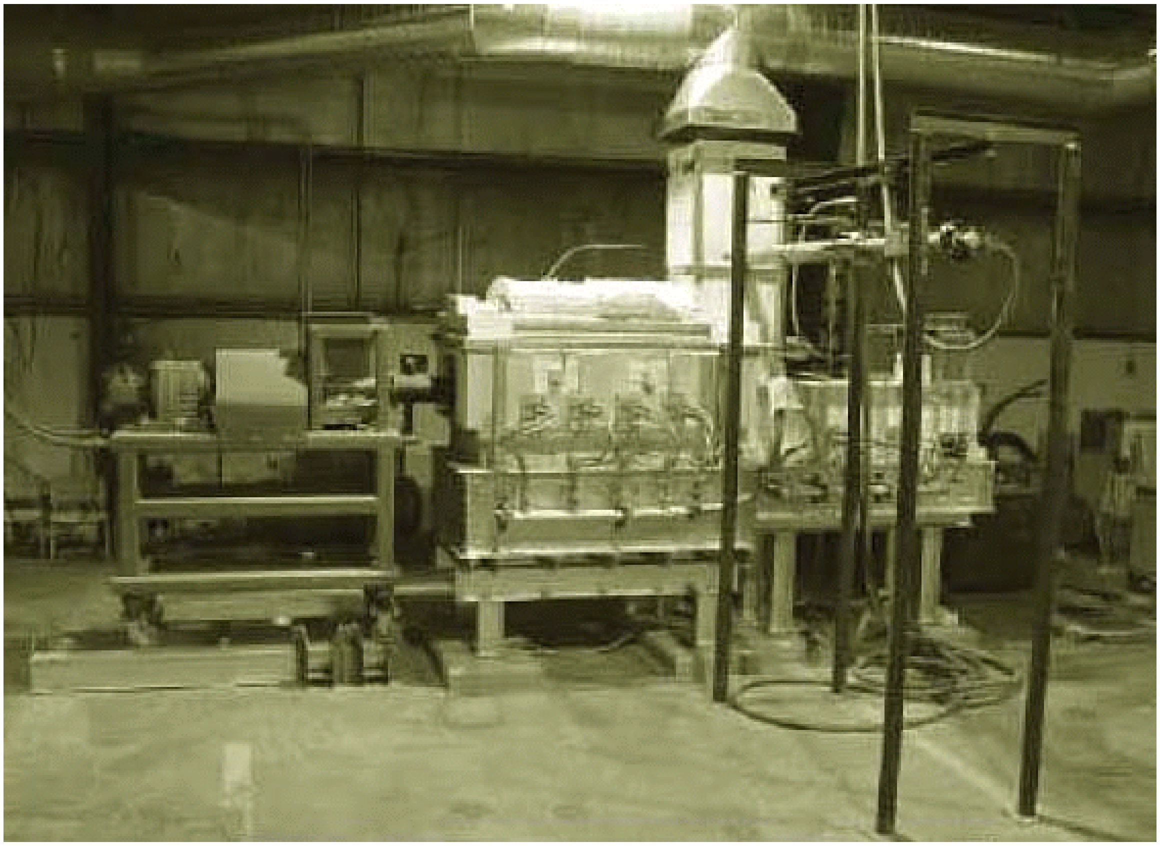

Figure 1-2 MELTER CONFIGURATION

in the exhaust gases to have the maximum residence time in the furnace, allowing these particulates to be melted or minimized.

The glass flowed under a skimmer block into a section of the glass furnace, called the forehearth. The forehearth was constructed in a conventional manner, with the glass outlet flowing to the water quench system. This method is used in other aggregate-making operations.

The pilot-scale melter was regulated by process controls. The controls used thermocouple signals to maintain a constant temperature and automatically adjust the gas and oxygen for each zone. Gas and oxygen delivered to the eight split-stream burners had several safety systems. The furnace is configured with oxygen and natural gas delivery systems with control and safety devices. If either natural gas or oxygen flow was lost, the system shut down that source. Each zone within the furnace was automatically regulated for gas and oxygen flows by a signal from the mass flow meter to a process control loop back to an automatic valve.

Refractory brick was selected by Minergy for the pilot-scale melter based on an evaluation of the abrasive qualities of the molten sediment and an analysis of thermal requirements. The analyses were conducted to ensure that the materials would not be used in temperatures beyond their specifications and to determine the total heat loss of the entire system.

1.5 KEY CONTACTS

Additional information on the GFT and the SITE Program can be obtained from the following sources:

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Information on the SITE Program is available through the following on-line information clearinghouses:

- EPA's Reach It, developed by the Technology Innovations Office
  http://www.epareachit.org
  REACH - IT combines information from three databases: Vendor Information System for Innovative Treatment Technologies, Vendor Facts, and Innovative Treatment Technologies

- CLU-IN
  http://www.clu-in.org
  CLU-IN provides information about innovative treatment and site-characterization technologies, while acting as a forum for all waste remediation stakeholders